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14. ABSTRACT
This program was broadly focused on the materials science of high temperature superconducting coated conductors, which are potential interest for application in electric power systems of interest to the Air Force. The three main elements were: 1) understanding the basic materials science underlying the deposition of 123 YBCO at the high rates needed for economic manufacture of coated conductors: 2) exploration of variants of and alternatives to 123 YBCO for possible application as coated conductors; and (in the early parts of the program) 3) development and application of in situ deposition process monitoring tools relevant to coated conductor deposition. Each of these is discussed in turn below. In addition some other topics were addressed as special opportunities that presented themselves as the program evolved. They are mentioned at the end of this report.

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Materials Science of High-Temperature Superconducting Coated Conductor Materials

M. R. Beasley
October, 2007

- ***Introduction:***

This program was broadly focused on the materials science of high-temperature superconducting coated conductors, which are of potential interest for application in electric power systems of interest to the Air Force. The three main elements were: 1) understanding the basic materials science underlying the deposition of 123 YBCO at the high rates needed for economic manufacture of coated conductors; 2) exploration of variants of and alternatives to 123 YBCO for possible application as coated conductors; and (in the early parts of the program) 3) development and application of in-situ deposition process monitoring tools relevant to coated conductor deposition. Each of these is discussed in turn below. In addition some other topics were addressed as special opportunities that presented themselves as the program evolved. They are mentioned at the end of this report.

- ***Materials Science of 123 YBCO***

In the early part of this program, we demonstrated the utility of *in-situ*, real-time Fourier Transform Infrared Reflectivity (FTIR) measurements as a potentially powerful tool to monitor the temperature and optical properties of a high Tc superconducting thin films during deposition. This work was then transferred to our DoE DURIP program, FA9550-07-1-0491, which was specifically focused on the development of new characterization tools. Once it was further developed under that program, in this program, we applied this technique to the study of the deposition process of high Tc YBCO thin films.

This new tool turned out to be spectacularly successful. Through its use, we were able to establish the phase stability lines (in temperature/oxygen pressure space) of the high temperature superconductor YBCO and to track the phase evolution of our deposits during both deposition and post deposition processing. We were able to establish in detail how our high-rate electron-beam co-evaporation process for coated conductors actually works. Specifically, we found that the initial deposit is a glassy material of partially oxidized cations (Y, Ba and Cu) that oxidizes further upon increasing the oxygen pressure in the deposition system and then enters the 123 YBCO stability region. Here the 123 phase forms along with a liquid BaCuO phase. We believe that our 123 YBCO grows from the BaCuO liquid flux as temperature is reduced subsequent to this initial oxidation. We certainly can see a change in the optical properties of our deposits that we associate with the BaCuO melting line in the phase diagram. Upon further reduction of temperature, further oxidation occurs to the fully oxidized form of 123 YBCO, which is the desired high temperature superconducting phase. Knowledge of this processing route now permits exploration of the optimal processing for 123 YBCO using electron beam co-evaporation. With this basic work in hand, this optimization work was transferred to our applied DoE Coated Conductor program.

As part of this program we also developed a depth profiling technique to study the dependence of the transport properties (normal state resistivity and superconducting critical current density) as a function of position down through the film. The basic idea was to measure the transport properties as successive layers were etched away. By taking the difference between successive measurements after each etching step, the value as a function of depth could be inferred. By this means, we were able to establish that our films were not homogeneous, but rather consisted of a top layer that had excellent properties and a lower layer that was nearly insulating. The origins of this layered nature of our films was finally understood later as a result of the detailed understanding we achieve with our FTIR studies mentioned above, supplemented by X-ray diffraction work.

- ***Advanced Materials for Coated Conductor Application – 248 YBCO***

The 248 phase of YBCO has the attractive feature compared with 123 YBCO that it has a stoichiometric oxygen concentration in the superconducting phase. Its drawback is that it has historically been hard to directly synthesize this material in thin film form, because of the high oxygen pressures required for equilibrium growth.

We have found a non-equilibrium process that can grow 248 YBCO in thin film form. In this process, a glassy precursor of the 248 phase is formed by PLD at elevated temperatures. Elevated temperatures are necessary to ensure high density and possibly short-range cation order. These precursor films are subsequently heat treated at a specific higher temperature and oxygen pressure. While the processing window is narrow, good 248 films do result. Time constraints on the program did not permit detailed physical characterization of these films for possible superconducting applications.

The astute reader will note that the synthesis routes for 123 and 124 YBCO both involve non-equilibrium processing from a glassy precursor. It is possible that these results presage a whole new approach to complex oxide thin film formation in general. A patent disclosure on the process has been submitted.

- ***Development of in situ Deposition Monitoring Tools***

The important introduction of FTIR as an in situ deposition monitoring tool was discussed above.

- ***Other Activities***

In the early part of this program, we characterized the thin films of MgB_2 that we had previously grown in an in situ process. They were found to be quite good, given the substantial difficulties to grown MgB_2 in situ.

Also, in an collaboration with the group of Jochen Mannhart at Augsburg, we invented a new memory cell for possible use with superconducting Joshephson electronics. The cell is based on switching of a magnetic dot with a single Josephson junction readout. The advantage of this cell over the traditional approach is that it holds the promise of being scalable to very small dimensions, well below that possible with the traditional cells.